North Pacific Fisheries Management Council
Bering Sea / Aleutian Islands King and Tanner Crab Working Group

Progress Report to the Crab Plan Team

20 September 2004

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I. Overview of the Statement of Work of the Working Group:

The Statement of Work [or Work Plan] of the Working Group defines the scope of responsibilities of the Group, and specifies proposed technical revisions to the Bering Sea / Aleutian Islands King and Tanner Crab Fishery Management Plan. A total of thirteen technical features of the FMP are identified as in need of revision to achieve Plan compliance with governing Federal laws, National Standards and Guidelines. Amendments to the Plan are presented in two sections of the Statement of Work: Revisions to the Plan [Section II], and Additional Technical Components to Implement in the Plan [Section III]. In each section, specific Action Items are identified for implementation. An overview precedes each item which provides the rationale for amending that element of the FMP. The value of each Action Item to the conservation and utilization of these stocks will be specified in the Environmental Assessment of the Plan amendment.

The following is excerpted from the Statement of Work [1.15.04]. The reader is referred to the full version of the Work Plan for a more complete description of the Action Items and the rationale for their inclusion in the Plan amendment. For consistency with the Statement of Work, we maintain here the numbering scheme of the thirteen Action Items per the Statement of Work. This scheme is: Action Items II.1 to II.3, and Action Items III.1 to III.10.

Section II: Revisions to the Plan

For stocks subject to this FMP, the threshold definition of overfishing, the definition as to whether the stock is overfished, and the overfishing control rule require revision. The SFA requires that status determination criteria specify both a maximum fishing mortality threshold [MFMT], and a minimum stock size threshold [MSST]. Stocks are assessed according to whether the maximum fishing mortality threshold is exceeded, and whether the stock is below the minimum stock size threshold. If the fishing mortality rate is above threshold, then overfishing is occurring. If the stock size is below the minimum threshold, then the stock is overfished. If overfishing is occurring, fishing mortality must be reduced so that stocks can produce maximum sustainable yield [MSY] on a continuing basis. For stocks that are overfished, rebuilding plans with an acceptable likelihood of success must be implemented to rebuild stocks to the MSY level within an appropriate time frame.

The National Standard 1 requires the adoption of conservation and management measures that prevent overfishing while providing optimum yield [OY] on a continuing basis. The advisory guidelines for NS1 recommend a precautionary approach to specifying OY. The precautionary approach guidelines identify MSY as the minimum standard for defining management limits. A principle feature of the precautionary approach to management is the definition of *limits* to safeguard long-term stock productivity. The NSGs define two limits for management that are required to insure stock conservation and yields close to MSY. These are the MFMT and MSST intended as benchmarks to gauge overfishing and overfished status criteria. The precautionary approach specifies *targets* that are set safely below these limits. Target setting considers uncertainty and other management objectives. Criteria used to set limit and target levels should be explicitly *risk averse*. Status determination criteria are used to evaluate limit and target reference point systems.

The Working Group will devise overfishing and overfished definitions, and MSY Control Rules for the stocks that are in compliance with governing Acts, and with their attendant Standards and Guidelines. The Amendment will specify thresholds to serve in determining if a stock is being overfished or if it's in an overfished state. It will specify the MSY control rule that intrinsically links these definitions for each stock.

Action Item II.1. Overfishing Definition:
A maximum fishing mortality rate [F] threshold [MFMT], or reasonable proxy thereof. Such a limit reference point, or F_{OFL}, will:

a. Represent the 'full-selection F' or the 'fully-recruited F' rate.
b. Encompass indirect losses to the stock as discards, and non-directed losses as bycatch from non-target fisheries.
c. Prescribe the F-based overfishing definition for the stock component exploited by the fishery - i.e., the exploitable stock biomass or its corollary, exploitable stock abundance.
d. Prescribe proxy overfishing definitions if required. Proxy definitions will be needed when the F_{MSY} cannot be estimated or when the estimated value is deemed unreliable [e.g., extremely low precision, insufficient contrast in the data, or inadequate models]. The choice among proxy measures must conform to the conservation requirements of the Acts in defining limits intended to safeguard the long-term productivity of the stock.

Action Item II.2. Overfished Definition:
A minimum stock size threshold MSST, or reasonable proxy thereof, expressed in terms of spawning biomass or other measures of reproductive capacity. The MSST should be the greater of either one-half the MSY stock size, or the minimum stock size at which rebuilding to the MSY level would be expected to occur within 10 years if the stock were exploited at the full MFMT. Formulation of this definition should satisfy:

a. The Act's conservation requirement of safeguarding the long-term productivity of the stock.
b. Where data allow, it would be derived in a structured modeling framework that reflects the species' essential biological and life-history characteristics, as well as its population and fishery dynamics.
c. Proxy overfished definitions should be scientifically defensible and supported by empirical evidence. Proxy definitions will be needed when the MSST cannot be estimated or when the estimated value is deemed unreliable [e.g., extremely low precision, insufficient contrast in the data,

or inadequate models]. The choice among proxy measures must conform to the conservation requirements of the Acts in defining limits intended to safeguard the long-term productivity of the stock.

Action Item II.3. MSY Control Rule:

In the National Standard Guidelines, the two limit definitions are intrinsically linked through an MSY Control Rule that specifies how the F threshold varies as a function of stock biomass to achieve continuing yields close to MSY. Control rules are pre-established plans for implementing management decisions without delay in response to changing status of the stock. The NSG1 states that the choice of a control rule should be guided by the characteristics of the fishery, the FMP's objectives and the best scientific information available. To minimize the occurrence of stock sizes for which rebuilding plans are required, the MSY Control Rule should afford *"built-in*" rebuilding as stock size declines below the MSY Stock Size.

Action Items Item III.7 and III.8 describes a method to link the Plan's MSY Control Rule to an integrated *Tier System* and *Limit Reference Point System*. Action Item III.9 discusses desirable properties of control rules to achieve in this amendment.

Section III. Additional Technical Components to Implement in the Plan

The Statement of Work specifies additional technical elements to implement in a Plan amendment required to meet Federal fisheries management responsibilities. Ten key fisheries scientific and technical components of the current FMP require amending. The Working Group acknowledges that additional elements may be included in order to achieve compliance of the FMP with the governing Acts, and with their attendant Standards and Guidelines.

Action Item III.1. Instantaneous Natural Mortality [M]:

The Amendment will:

a. Describe the method that will be used to estimate M for each crab species subject to this Plan.
b. Describe how the rate M will be applied in the overfishing definition and in the MSY Control Rule for each stock.

Action Item III.2. Plan Overfishing Definition and Z_{MSY}:

The Amendment will:

a. Describe how Z_{MSY} will operate as a limit reference point for each stock.
b. Describe how Z_{MSY} will be applied in the overfishing definition and the MSY Control Rule for each stock.
c. Describe how Z_{MSY} will be applied in assessing the performance of the fisheries and the adopted conservation and management measures.

Action Item III.3. Instantaneous Fishing Mortality [F] and Exploitation Rate [u]:

The Amendment will:

a. Describe how the fully-recruited F rate and fishery selectivity will be employed to derive the exploitation rate corresponding to the target or threshold F definitions in the Plan.

b. Prescribe what is the exploited component of each stock that is subject to the target or threshold Fs in the Plan.

Action Item III.4. Non-Directed Mortalities and Overfishing Definitions:

The Amendment will:

a. Describe how discard mortalities will be employed to derive the exploitation rate corresponding to the target and threshold F rates specified in the Plan.

b. Describe the approach to estimate the discard loss rates from the directed fishery for each stock, or the values of those rates.

c. Describes the approach to estimate the bycatch loss rates from the non-directed fisheries for each stock, or the values of those rates.

Action Item III.5. Biomass B_{MSY} and Sustainable Yield [SY]:

The Amendment will:

a. Describe the approach to estimate B_{MSY} or a proxy thereof.

b. Prescribe the exploitable abundance component of the stock to be used to estimate harvest goals.

c. Describe the approach to estimate catch standards using the exploitation rate corollary to the target F on the exploitable component of the stock.

Action Item III.6. Conservation Equivalency:

The Amendment will:

a. Specify the approach of Conservation Equivalency which will serve to maintain stock biomass standards established in the Plan.

b. Identify the currency of measure for determining the equivalent conservation value used to adjust the MSY Control Rule in response to exceeding overfishing definitions in the Plan.

c. Describe the analytical framework to be applied in the Plan's MSY Control Rule for target rate setting that would achieve stock conservation equivalency and the specified stock biomass standards.

Action Item III.7. Tier System for Defining Overfishing Definitions:

The Amendment will:

a. Define a Tier System for prescribing the threshold overfishing definitions for each stock.

b. Formulate the system for setting F_{OFLs} that considers both the status of knowledge and its uncertainty, and the status of the stocks.

c. Describe the approach for formally integrating the Tier System and the

Limit Reference Point System [see Item II.8] for prescribing target or threshold fishing mortality rates for each stock.

Action Item III.8. Limit Reference Point System:
The Amendment will:
a. Identify the suite of LRPs essential to gauging stock and fishery status.
b. Define a Traffic Light System for the status of stock and fishery assessment that is integrated in the MSY Control Rule.
c. Describe the method of enumerating annual SOS that would replace the current determination of stock biomass relative to threshold.
d. Define the limit reference point system and its use in a control rule that specifies the F Buffer Zone, F Target Zone and F Overfishing Zone.
e. Define the method to link the Limit Reference Point System and the Tier System for prescribing the maximum fishing mortality threshold or target F rates for each stock.
f. Prescribe how these combined systems would be used to set F_{OFL} values appropriate to the current status of the stock and fisheries.

Action Item III.9. Projection Modeling Framework:
The Amendment will:
a. Define a suitable analytical framework for examining the consequences of alternative conservation and management measures on stock status.
b. Specify the performance criteria that will be examined in the process of evaluating harvest strategies and decision rules.
c. Define a general simulation framework for developing rebuilding plans that achieve stock recovery in the requisite time frame. Plan components will specify both the rebuilding period and rebuilding trajectory.
d. Define a general simulation framework that would specify the rebuilding control rule for each stock under a rebuilding plan.
e. Define an analytical framework that would prescribe the overfishing control rules for each stock.

Action Item III.10. Sensitivity Analysis:
The Amendment will:
a. Identify the important fishery and stock parameters whose variation would affect the overfishing and overfished threshold definitions.
b. Define an analytical framework that would be used to conduct sensitivity analyses of these reference points for each stock.
c. Define an analytical framework that would be used to select robust overfishing and overfished values based on sensitivity analyses.
d. Identify the critical information needs for management which would guide research planning for these stocks.

II. **Work Plan Presentation to SSC:**

In February 2004, Lou Rugolo and Shareef Siddeek presented the Working Group Statement of Work to the Scientific and Statistical Committee of the North Pacific Fishery Management Council. The following are the SSC's comments on the Work Plan as extracted from the NPFMC's Minutes of the February 2004 SSC meeting:

> Lou Rugolo (NMFS) and Shareef Siddeek (ADF&G) presented an overview of the progress of their working group to revise the overfishing definitions in the crab FMP. Public comment was provided by Arni Thomson of the Alaska Crab Coalition.
>
> The crab working group is comprised of four members, two from NMFS and two from ADF&G. When the overfishing definitions were originally developed by the crab plan team, they had intended that they be revisited in a period of 5 years or so. Now, 5 years later, this working group is embarking on this task. In its September 2003 meeting minutes, the crab plan team specified that the charge of the working group is to "lead the analysis of a new FMP amendment to revise overfished/overfishing definitions."
>
> The SSC believes that it is appropriate to undertake a review of these crab plan definitions. A number of inconsistencies and unnecessary complexities have been uncovered, and improvements can be made.
>
> Top priority should be given toward a careful examination and revision of the definitions of overfishing and overfished, as indicated by the crab plan team. In the course of embarking on this priority task, other closely related issues must be reevaluated, such as B_{MSY}, natural mortality rate (M), MSST, and MFMT. There is a linkage among all these parameters, so population simulation modeling, biomass dynamic modeling, and yield-per- recruit analyses would inform this analysis. For instance, MFMT should be considered under alternative definitions of MSST in the context of stock rebuilding and attainment of other management objectives. Effects of natural variation in recruitment and uncertainty in stock assessments and mortality on these estimates should be considered.
>
> The SSC notes that the estimation of M and B_{MSY} is difficult for these crab species. For instance, estimates of B_{MSY} depend upon the period over which data are used, and the choice of the appropriate time period may be subjective. The current FMP defines overfishing using explicit values of M for king and Tanner crab stocks that were developed based on estimates of longevity. As new estimates of M are developed, the SSC recommends frame working these definitions in the FMP so that future plan amendments are unnecessary when new data and analyses result in new estimates of M.
>
> The working group discussed an intention to explicitly link M estimates in population models with M estimates used in harvest control rules. The SSC supports this goal, but also notes that there could be reasons for these two sets of estimates to differ. First, M used to define harvest control rules may be based

on life history considerations, whereas M may be estimated internal to the population dynamic model such that best fits are attained. However, survey catchability and selectivity are confounded with M in population models, so neither one of these parameters may be estimated with much confidence. It may be possible to craft a stock assessment scenario, in which M is fixed at the same level as in the harvest control rule, allowing catchability and/or selectivities to be estimated. Second, to the extent that some crab stocks apparently experience large, short-term increases in M perhaps due to disease or environmental causes, it may be undesirable to trigger commensurate increases in F at a time of population crash. Presumably, this would be the outcome if population model estimates of M were directly translated into harvest policy. Instead, simulation modeling can be used to develop long-term harvest policies that are more risk averse to these and other uncertainties in stock dynamics.

The SSC recommends that the working group consider one additional facet in their work plan. Typically, crab abundance is estimated by summer crab surveys or population models that incorporate summer survey data. To estimate the overfishing level, MFMT should be applied to estimated crab abundance at the time of the fishery. As crab fisheries occur in fall or winter, summer crab abundance should be discounted for the natural mortality that occurs between the time of the survey and the time of the fishery. Failure to do so results in misapplication of the overfishing definition.

Since the analysis has not yet been conducted, statements made during the presentation suggested that a plan amendment could include higher estimates of B_{MSY}, higher MSSTs, lower estimates of M, lower MFMTs, and perhaps lower target harvest rates to stay safely below MFMT. Such statements should be avoided until the analyses are completed and reviewed.

As a plan amendment is developed, it should be brought forward to the NPFMC and Alaska Board of Fisheries on parallel tracks. This should be workable, as the Board of Fisheries is scheduled to address BSAI crabs in March 2005.

For its next meeting, the SSC asks the working group to present an outline of the new draft control rule system that might be applied to BSAI crabs. A more formalized procedure for setting overfishing levels, such as the tier system for groundfish, is preferred. Like the groundfish tier system, rather than a constant F limit reference point, the working group should consider scaled-down reductions in F_{OFL} as the stock declines to low levels.

III. **Working Group Meetings:**

To date, the WG has met on four occasions [11/03, 03/04/ 06/04 and 09/04]. The next meeting is tentatively scheduled for November 2004. Work progresses on many fronts and notable progress has been made on key components of the Work Plan. The agendas for each of the meetings are appended to this Progress Report to provide context and understanding of our work and considerations during this time.

IV. Approach to Estimate Biological Reference Points for Bering Sea and Aleutian Island Crab Stocks: Preliminary Deterministic Calculations Using Bristol Bay Red King Crab Stock Information

Introduction

The proposed new tier system for BSAI crab stocks identifies F_{MSY} and B_{MSY} as limit reference points for data rich stocks (Tiers 1&2) and it prescribes F% and corresponding spawning biomass ratio (B%) as limit reference points for data poor stocks (Tiers 3 to 5). We are currently looking into Clark's (1991, 1993, 2002) approach and modifying his method to suit crab biological characteristics and estimate F% and B% for data poor stocks. Our approach is as follows:

1. Estimate F% for the Bering Sea and Aleutian Islands (BSAI) crab stocks with standard deterministic stock-recruitment (S-R) relationships (Beverton-Holt (1957) and Ricker (1954)). We used the Bristol Bay red king crab (a data rich stock) population dynamics parameters to test whether Clark's (1991) method of F% estimation is suitable for crab stocks. Preliminary estimate of F% under one scenario, sensitivity of that F% value to equilibrium recruitment and biomass are reported here.

2. Estimate the same biological reference points following a stochastic approach using the same two S-R models, adding variability to the recruitment generated by the two deterministic S-R models and fishing mortality (which takes account of abundance variability). Perform sensitivity analysis of important parameters (different M levels, high and low molt probability, high and low handling mortality) on the biological reference points. Assess the mean yield, variability of yield (e.g., CV of yield), and probability of stock collapse in a time horizon under a given F%.

3. Repeat Task #2 under a completely random recruitment scenario (i.e., no S-R relationship exists, see Booth (2004)).

4. Repeat Task #2 with a Beverton-Holt S-R depensation model (Myers et al. 1995).

Method 1. Estimation of F% Using Bristol Bay Red King Crab Stock Parameters

The Bristol Bay red king crab stock parameters (Zheng unpublished), except a lower M and a lower productive stock-recruitment curves, were used to test Clark's (1991) deterministic per-recruit analysis approach in determining F%. Clark determined F% (his estimate for the typical groundfish based on deterministic S-R relationship was F35%) by identifying a relative spawning biomass-per-recruit (SSB/R) value that corresponds to the **maximum of minimum** relative yields (yield / MSY) for a range of relative SSB/R values. Once the F% is determined, the exact full-recruitment fishing mortality (in Clark's notation F_{MMY}) can be estimated using the relative SSB/R vs. F curve.

We first identified the probable range of steepness parameter values (Tau) of the standard S-R curves based on the assumption that high Tau values, which lead to the stock collapse at F < 2M and low Tau values that do not cause the stock collapse at F > 7M, were improbable. Clark (1991) used the similar criteria to select his D range (which is equivalent to 1/Tau). The difference between our approach and Clark's approach is that Clark assumed recruitment and maturity at the same age to select his Tau range whereas we assumed maturity at younger age than recruitment. Our approach results in lower productive stock-recruitment curves than Clark's approach. Then we estimated various yield and biomass quantities using the base parameter values, S-R relationship, and the selected range of Tau values – yield (Y), equilibrium relative yield (Y/MSY), equilibrium relative spawning biomass (SSB/SSB_0), equilibrium relative recruitment (R/R_0), and equilibrium relative spawning biomass-per-recruit [$(SSB/R)/(SSB/R)_0$] where the subscript 0 represents virgin levels. We plotted these values to identify F% and investigate its effect on relative recruitment and relative spawning stock biomass.

Only a constant M scenario, medium molt probability, 20% handling mortality, retained selectivity, discard selectivity, maturity probability, gamma growth increment probability, and a fixed medium mating ratio (1:2) were used in the deterministic simulation model (Table 1). The reference points were estimated under two scenarios: (1) using an effective spawning biomass-per-recruit, which incorporates a mating ratio (say ESB), and (2) using a total mature biomass-per-recruit, which disregards the mating ratio and assumes all mature crabs participate in spawning (say SSB). In this report, we present only those results for the second scenario (i.e., for SSB). We caution the readers that the results presented in this report are very preliminary and the simulation models are still being improved.

Results

Choosing a Tau range:

Figure 1(a) provides equilibrium yield against full-recruitment fishing mortality (F) under scenario 2 (SSB) for the Beverton-Holt S-R model. A Tau (Mace 1994) range of 0.35 – 0.5 was selected as appropriate for this scenario. Tau values above 0.5 suggest that the stock is not sustainable with an F < 2M (very unlikely) and Tau values below 0.35 suggest that the stock can sustain long term F above 7M without collapse (another unlikely scenario).

Spawning stock biomass range to produce above 75% MSY:

For the Tau range 0.35 – 0.5, the spawning stock biomass within an approximate range of 20-60% of virgin spawning biomass produces above 75% of MSY under deterministic Beverton-Holt S-R relationship and scenario 2 (Figure 1(b)). Thus, as long as the spawning biomass is kept within this range of the virgin biomass, a larger portion of MSY can be harvested. This is a biomass-based harvest strategy. But difficulty arises when estimating the biomass ratio because virgin biomass is largely unknown.

F%:

Figures 1(c) and (d) depict the relative Y against the relative SSB/R (Scenario 2) for the deterministic Beverton-Holt S-R model. The maximum of the minimum yield at each relative SSB/R for selected range of Tau values (Clark named it as 'maximinyield') was identified in

Figure 1(c). The F% was F66% corresponding to an F_{MSY} of 0.14 (Figure 1(d)), which is equal to a legal harvest rate of approximately 13% for Bristol Bay red king crabs.

Effect of F% on equilibrium recruitment:
Figure 1(e) shows the relative recruitment vs. relative SSB/R (Scenario 2) for the deterministic Beverton-Holt S-R model. The fishing mortality equal to or lower than F66% level maintains the equilibrium recruitment above 50% of the maximum recruitment under a favorable environmental condition. In the literature (e.g., Myers et al. 1994), the F that produces 50% of the maximum R has been identified as a limit reference point.

Effect of F% on equilibrium biomass:
Figure 1(f) depicts the relative SSB vs. relative SSB/R (Scenario 2) for the deterministic Beverton-Holt S-R model. The fishing mortality equal to or lower than F66% level maintains the equilibrium spawning biomass well above 20% of the virgin spawning biomass. In the literature (e.g., Beddington and Cooke 1983), the 20% of the virgin spawning biomass level has arbitrarily been set as a lower limit below which stock might collapse.

Summary

1. Under deterministic population dynamics scenario, it appears that F66% full-recruitment fishing mortality on Bristol Bay legal male red king crabs at the time of the fishery would produce a long term harvest above 75% MSY, maintain above 50% recruitment (under a favorable environmental condition), and maintain above 20% of virgin spawning stock biomass. However, the results should not to be treated as conclusive because of a number of restrictive assumptions (e.g., low S-R productivity due to selection of a particular Tau range) made in the preliminary analysis at the model developmental stage. We will further investigate the appropriateness of the Tau range in light of disjoint selectivity and maturity schedules for crab species (which is different from what Clark has assumed in his groundfish analysis).

2. Further refinement of simulation models, including stochastic simulation models, sensitivity analyses of key parameters on biological reference points, and estimation of stock productivity under various scenarios, are in progress.

3. The refined simulation models will be applied to five major BSAI crab stocks: Bristol Bay red king crab, Bering Sea snow crab, Bering Sea Tanner crab, St. Mathew Island blue king crab, and Aleutian Islands golden king crab. General conclusions on F% and corresponding B% values will be made for other data-poor crab stocks based on results of those five stocks.

References

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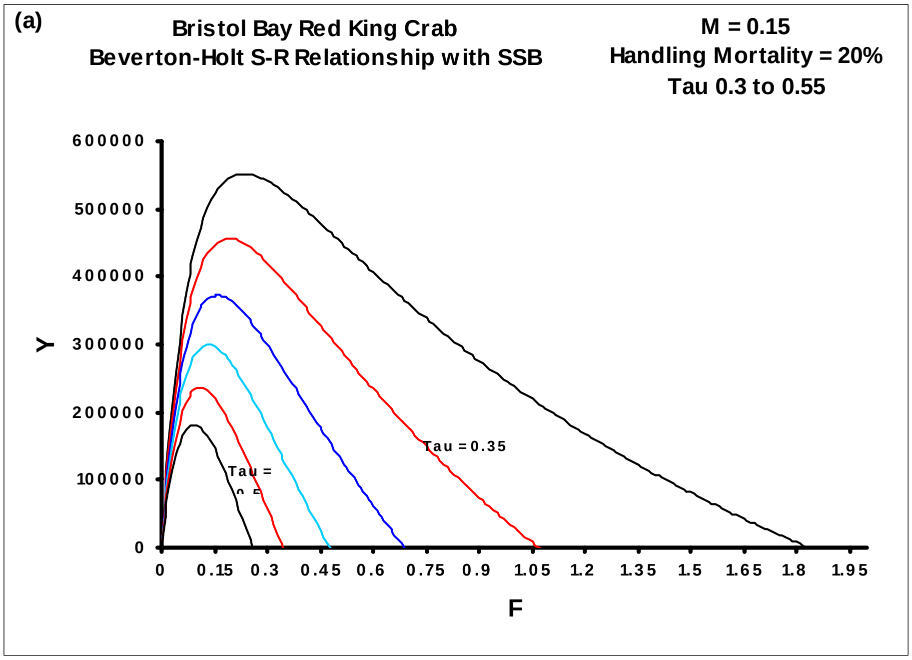
Table 1. Input parameters (base values) for Bristol Bay red king crab for reference point estimation. CL = carapace length.

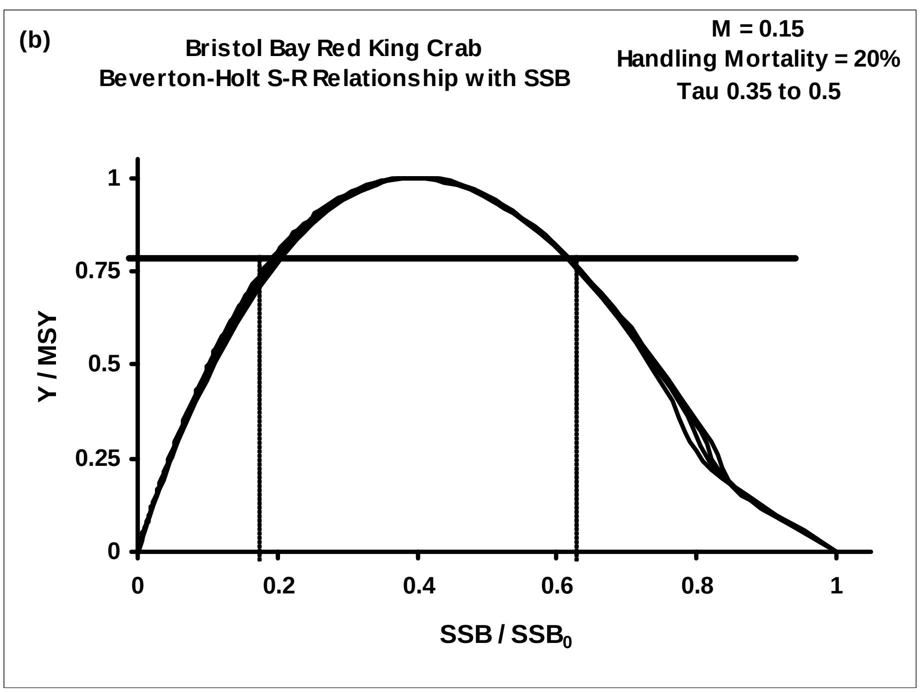
Parameter	Male		Female	
	PreRecruit 1	Recruit & PostRecruit	Class 1	Class 2
Size Range (mm CL)	95-129	135-169	90-119	120-139
Natural Mortality (M)	0.15	0.15	0.15	0.15
Handling Mortality	0.20		0.20	0.20
Mean Fishing Period, 1966-03 (yr^{-1}), δ		0.01136		
Mean Lapsed Time Between Mid-Molt and Start of Fishing Period (yr^{-1}), *T*		0.625		
Growth Increment Linear Model: a, b	17.54158	-0.01558	16.7	-0.09846
Growth Increment Gamma Probability: beta	Male: 0.653		Female: 1.018	
Recruitment Gamma Probability: mean, beta	107	1.252	97	0.456
Maturity Probability: Logistic *a, b*	$5.734\ 10^{13}$	-0.264	$1.262\ 10^{11}$	-0.2872
Molt Probability: Reverse Logistic *a, b*	Intermediate: 3.53885.31, 0.09		Probability = 1.0	
Pot Selectivity Probability, Retained: Single Logistic *a, b*	0.66438, 137.50334 (Retained)		Constant Selectivity = 0.255	
Discards: Double Logistic *a, b, c, d*	0.07456, 113.30948, 0.59615, 137.18722			
Mating Ratio (Male:Female)	1:2		1:2	
Weight-Length Model (g-mm): *a, b*	0.0003614, 3.16		0.02286, 2.234	

Figures 1(a) through 1(f):

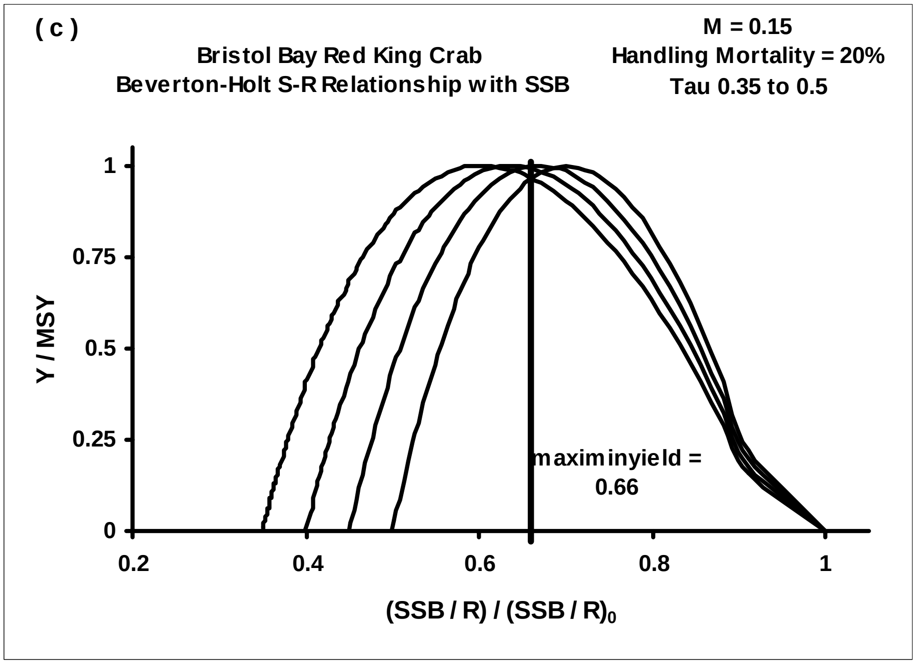
Equilibrium yield, spawning biomass, and recruitment for a range of Beverton-Holt spawner-recruit (S-R) curves for Bristol Bay red king crab, where subscript 0 represents unfished levels. The spawners are total spawning biomass without considering any mating ratio, M = 0.15, directed fishery handling mortality rate = 20%, and non-directed fisheries instantaneous bycatch mortality = 0.01.



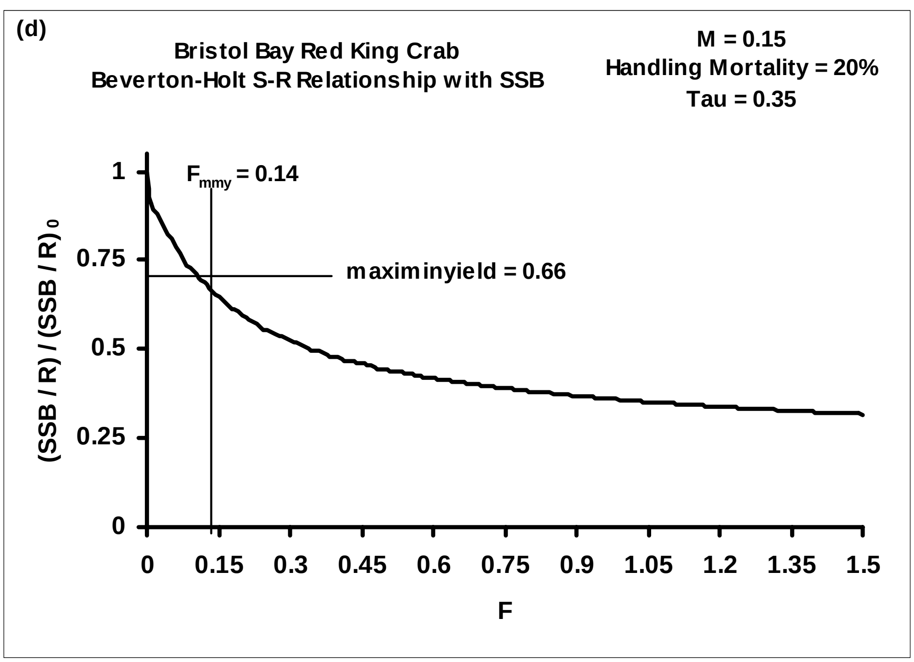
(a). Equilibrium yield (Y) vs. fishing mortality (F) for a Tau range 0.3 - 0.55.



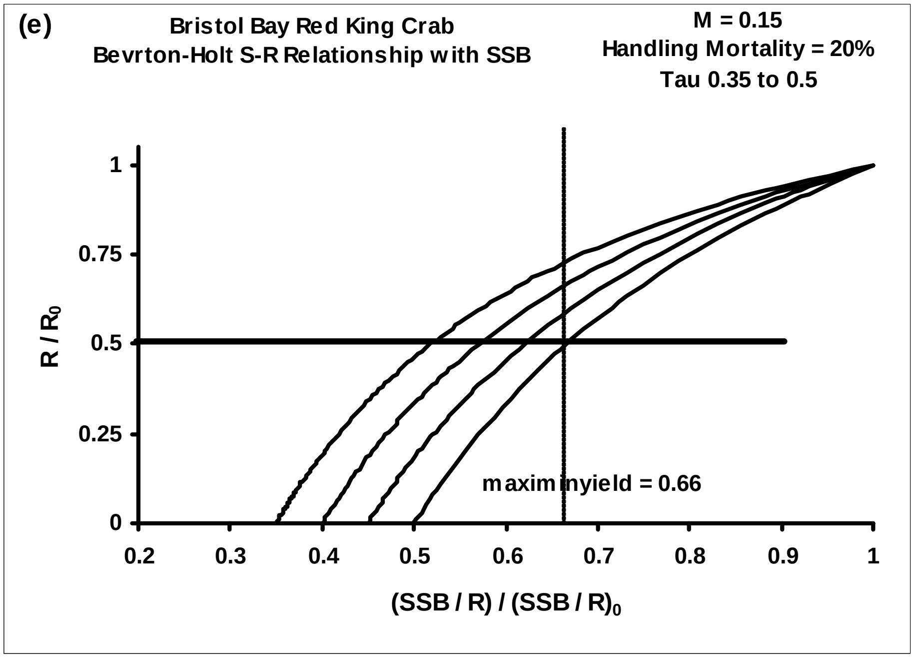
(b). Relative yield (Y/MSY) vs. relative spawning stock biomass (SSB/SSB_0) for a Tau range 0.35 - 0.5.



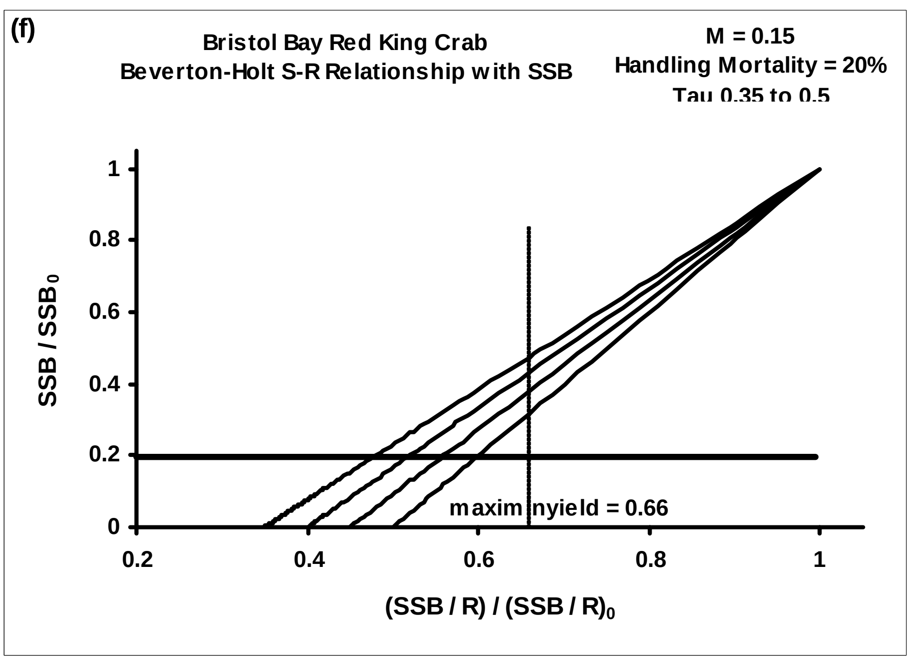
c). Rel
ative yield (Y/MSY) vs. relative spawning stock biomass-per-recruit $(SSB/R)/(SSB/R)_0$ for a Tau range 0.35 - 0.5.



(d). Relative spawning stock biomass-per-recruit $(SSB/R)/(SSB/R)_0$ vs. F for Tau = 0.35.



(e). Relative recruitment (R/R_0) vs. relative spawning stock biomass-per-recruit $(SSB/R)/(SSB/R)_0$ for a Tau range 0.35 - 0.5.



(f). Relative spawning stock biomass (SSB/SSB_0) vs. relative spawning stock biomass-per-recruit $(SSB/R)/(SSB/R)_0$ for a Tau range 0.35 - 0.5.

V. A Tier System for Bering Sea / Aleutian Island King and Tanner Crab Stocks

The Current Tier System for BSAI King and Tanner Crab Stocks (Crab FMP 1998)
The existing tier system is based mostly on the amount of survey information since survey data is used to estimate overfishing definitions. Tier 1 is the least amount of information, tier 3 the most information. Overfishing is evaluated by comparing MSY (includes mature males and females) to the Guideline Harvest Level (GHL) (includes retained males only, no bycatch).

Tier 1. Crab stock is not surveyed. Some catch data available.
F_{MSY} = M = 0.2 (King), 0.3 (Tanner and snow)
B_{MSY} not estimable
MSY is estimated from a proxy of mature biomass and stock utilization rate

Tier 2. Sporadic or limited years of survey data. Catch and effort data on each crab stock is well documented.
F_{MSY} = M = 0.2 (King), 0.3 (Tanner and snow)
B_{MSY} not estimable
MSY is estimated from a proxy of mature biomass and stock utilization rate

Tier 3. Data available: historical catch, continuous inseason catch and effort data, stock assessment, growth, maturity, limited natural mortality and stock recruitment relationship information.
F_{MSY} = M = 0.2 (King), 0.3 (Tanner and snow)
B_{MSY} is the average survey biomass of mature males and females from 1983 to 1997
MSY = F_{MSY} x B_{MSY}

MSY has been estimated for all stocks except Aleutian Islands scarlet king and Eastern Bering Sea scarlet king crabs.

Draft Tier System for BSAI King and Tanner Crab Stocks
The proposed tier system has six tiers that have been modified from the current NPFMC groundfish tier system. Tiers are based on whether reliable estimates are available for biomass (survey or model) and reference points, and whether a model has been implemented for the assessment. Tiers 1 through 3 are for stocks with length or age structured models which incorporate survey and fishery data. For tiers 1 through 3, reliable estimates of necessary input data and parameters are needed for models that provide estimates of a time series of B, and of Bmsy and Fmsy or their proxies. Stocks in tiers 1 through 3 do not necessarily have annual surveys, however surveys and other information have to be reliable to be used in a stock assessment model. Tiers 1 and 2 are for stocks with a reliable estimate of the spawner recruit relationship. Tier 1 is for stock assessments where the probability density function of F_{MSY} is estimated. Tier 3 is for stocks where reliable estimates of the spawner recruit curve are not available, however, proxies for $F_{MSY,}$ B_{MSY} and F_{Target} can be estimated.

F_{ABC} is the maximum target F to ensure a buffer between the overfishing F and the target F as required by National Standard Guidelines 1 (NSG1). The setting of the target F has been deferred to Alaska Department of Fish and Game (ADF&G) with oversight by the Federal Government. The target F corresponding to the annual quota can be set anywhere below the F_{OFL} however, to comply with NSG1 there must be a buffer between the target F and the F_{OFL} to ensure that the F_{OFL} is not exceeded.

Tiers 4 through 6 are for stocks with no stock assessment model. The MSY control rule for tiers 4 and 5 declines with B similar to tiers 1-3, however, a proxy for B_{Target} is estimated based on survey data instead of through modeling. Tier 4 is where maturity information and other life history information are available to estimate proxies for F_{MSY} and F_{Target} however, there is no stock assessment model. B_{Target} would need to be determined based on survey data. Tier 5 stocks have no estimates of proxy F_{MSY} or F_{Target} so a default value of M is used, i.e. there is a reliable estimate of current biomass (survey biomass) and of M. Tier 6 stocks have no reliable estimates of biomass and/or M, so catch history is used to set limits and targets in terms of catch instead of fishing mortality.

The control rule reduces F as biomass declines for tiers 1 through 5 (groundfish control rule reduces F for tiers 1 through 3 only). A proxy for B_{Target} would need to be estimated for tiers 4 and 5. The groundfish control rule uses an α of 0.05 (F is zero at 0.05 x B_{MSY}), uses F35% as a proxy for F_{MSY} and F40% as a target F when F_{MSY} is not estimable. The proxy values are being determined for crab stocks based on modeling work. Biomass values for groundfish are female spawning biomass. Crab stocks will use effective spawning biomass, which incorporates female and male spawning biomass with an adjustment for the mating ratio. If there are not enough mature males to fertilize females, then the effective spawning biomass will be lowered. This requires assumptions regarding the optimum mating ratio and the component of the male stock that is effective at mating. All mature males may not be successful at mating depending on their size and molt history.

The proposed tier system for crabs incorporates a relative biomass value (β) below which F is 0 (Figure 1). This would result in F=0 at a biomass value most likely above the value implied by α. For example, the current harvest strategy for Bering Sea snow crab (not the overfishing definitions) reduces fishing mortality to 0 at 25% of B_{MSY}.

Tiers:

1. Information available*: Reliable point estimates of B and* B_{MSY} *and reliable pdf of* F_{MSY}

   a. Stock status: $B/B_{MSY} > 1$
      $F_{OFL} = \mu_A$, *the arithmetic mean of the pdf*
      $F_{ABC} \leq \mu_H$, *the harmonic mean of the pdf*

   b. Stock status: $\beta < B/B_{MSY} \leq 1$
      $F_{OFL} = \mu_A \times (B/B_{MSY} - \alpha)/(1 - \alpha)$
      $F_{ABC} \leq \mu_H \times (B/B_{MSY} - \alpha)/(1 - \alpha)$

   c. Stock status: $B/B_{MSY} \leq \beta$
      $F_{OFL} = 0$
      $F_{ABC} = 0$

2. Information available: *Reliable point estimates of B,* B_{MSY}, F_{MSY}, F_{Limit} *(proxy for* F_{MSY}*), and* F_{Target}. *The F% proxies for* F_{MSY} *and* F_{Target} *would need to be determined for crab stocks*.

   a. Stock status*:* $B/B_{MSY} > 1$
      $F_{OFL} = F_{MSY}$
      $F_{ABC} \leq F_{MSY} \times (F_{Target}/F_{Limit})$

   b. Stock status*:* $\beta < B/B_{MSY} \leq 1$
      $F_{OFL} = F_{MSY} \times (B/B_{MSY} - \alpha)/(1 - \alpha)$
      $F_{ABC} \leq F_{MSY} \times (F_{Target}/F_{Limit}) \times (B/B_{MSY} - \alpha)/(1 - \alpha)$

   c. Stock status:: $B/B_{MSY} \leq \beta$
      $F_{OFL} = 0$
      $F_{ABC} = 0$

3. Information available: *Reliable point estimates of B,* B_{Target}, F_{Limit}, F_{Target}. *The F% and B% proxies for* F_{MSY}, F_{Target} *and* B_{Target} *would need to be determined for crab stocks.*

   a. Stock status*:* $B/B_{Target} > 1$
      $F_{OFL} = F_{Limit}$
      $F_{ABC} \leq F_{Target}$

   b. Stock status*:* $\beta < B/B_{Target} \leq 1$
      $F_{OFL} = F_{Limit} \times (B/B_{Target} - \alpha)/(1 - \alpha)$
      $F_{ABC} \leq F_{Target} \times (B/B_{Target} - \alpha)/(1 - \alpha)$

   c. Stock status:: $B/B_{Target} \leq \beta$
      $F_{OFL} = 0$
      $F_{ABC} = 0$

4. Information available: *Reliable point estimates of B, F_{Limit}, F_{Target}. No stock assessment model, but reliable estimate of a proxy for $B_{Target\%}$ based on survey data. The F% and B% proxies for F_{MSY}, F_{Target} and B_{Target} would need to be determined for crab stocks.*

   a. Stock status: $B/B_{Target} > 1$
   $F_{OFL} = F_{Limit}$
   $F_{ABC} \leq F_{Target}$

   b. Stock status: $\beta < B/B_{Target} \leq 1$
   $F_{OFL} = F_{Limit} \times (B/B_{Target} - \alpha)/(1 - \alpha)$
   $F_{ABC} \leq F_{Target} \times (B/B_{Target} - \alpha)/(1 - \alpha)$

   c. Stock status:: $B/B_{Target} \leq \beta$
   $F_{OFL} = 0$
   $F_{ABC} = 0$

5. Information available: *Reliable point estimates of B and natural mortality rate M. No stock assessment model, but reliable estimate of a proxy for B_{Target} (B% would need to be determined for crab stocks) based on survey data. There may need to be a multiplier on natural mortality (γ) to get F_{OFL} if M is determined not to be a good proxy for a target F for crab stocks.*

   a. Stock status: $B/B_{Target} > 1$
   $F_{OFL} = \gamma \times M$
   $F_{ABC} \leq 0.75 \times F_{OFL}$

   b. Stock status: $\beta < B/B_{Target} \leq 1$
   $F_{OFL} = \gamma \times M \times (B/B_{Target} - \alpha)/(1 - \alpha)$
   $F_{ABC} \leq 0.75 \times F_{OFL} \times (B/B_{Target} - \alpha)/(1 - \alpha)$

   c. Stock status:: $B/B_{Target} \leq \beta$
   $F_{OFL} = 0$
   $F_{ABC} = 0$

6. Information available: *Reliable catch history from a time period to be determined (groundfish uses 1978 through 1995). Need to evaluate 0.75 reduction for crab stocks.*

   OFL = the average catch from a time period to be determined, unless an alternative value is established by the SSC on the basis of the best scientific information available.

   $ABC \leq 0.75 \times OFL$

Incorporating the Limit Reference Point System into the Tier System

The limit reference point system proposed for crab stocks would result in an overall score based on scores for individual components of the health and status of a stock. This overall score would be used to adjust the Fofl and Fabc values in the above tier system. The scoring system, which tiers to apply it to and the method of application will be recommended by the working group.

Current tier system assignment

<u>Tier 1 stocks</u>

Pribilof Islands golden king
Saint Matthew golden king
Western Aleutian Tanner crab ©. bairdi)
Saint Lawrence Island blue king
Aleutian Islands scarlet king
Bering Sea triangle Tanner
Eastern Aleutian Islands triangle Tanner
Eastern Aleutian Islands grooved Tanner
Western Aleutian Islands grooved Tanner
Bering Sea grooved Tanner

<u>Tier 2 stocks</u>

Adak red king
Dutch harbor red king
Norton Sound red king
Aleutian Islands golden king
Eastern Aleutian Islands Tanner (bairdi)

<u>Tier 3 stocks</u>

Bristol Bay red king
Pribilof Islands red king
Pribilof Islands blue king
Saint Matthew Island blue king
Bering Sea C. bairdi Tanner
Bering Sea C. opilio snow

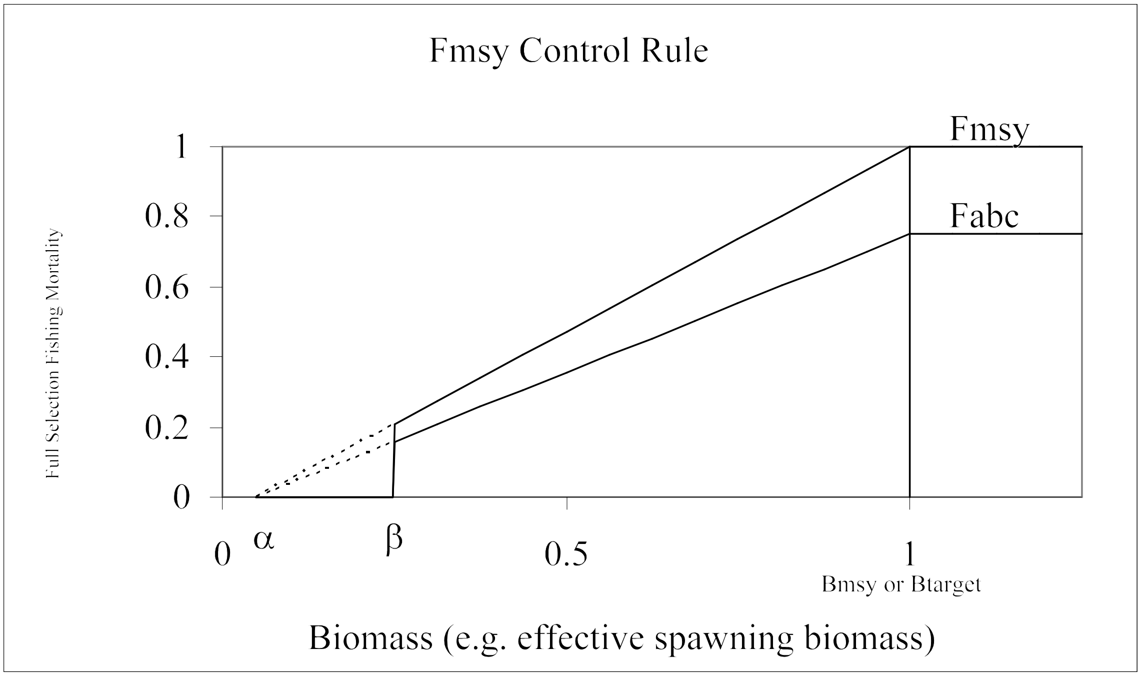


Figure 1. F_{MSY} Control Rule Example.

VI. **Tier System Presentation to the SSC:**

In June 2004, Jack Turnock presented the draft Tier System for BSAI King and Tanner Crab Stocks to the Scientific and Statistical Committee of the North Pacific Fishery Management Council. The following is an overview of the SSC's comments on the Work Plan from notes taken by the presenter.

In general, the SSC thought that the draft tier system was good, and liked that it was based on the groundfish tier system.

The SSC reviewed comments on the overfishing definitions when they were last before the SSC in June 1998. The SSC had reservations about the overfishing definitions, wanted them to be similar to groundfish, did not want fixed numerical values in the FMP, did not think average survey biomass over some time period was a good proxy for B_{MSY} as the average biomass depends on the F that was occurring at the time.

In the April 1998 minutes the SSC noted that there was no clear definition of how overfishing would be determined, which is true for the final version of the BSAI King and Tanner Crab Plan. The SSC also did not like the use of the ratio of catch to mature biomass to come up with proxy values of B_{MSY} for stocks with little survey data.

Summarized comments:

1. Include density dependent effects, e.g., growth, maturity if there is evidence that they occur for crab stocks
2. Change F_{PMSY} (the proxy for F_{MSY}) in the tier system to F_{Limit}.
3. Initially he thought that Alternative 2 (fixed reference points) should be eliminated now, however, since many members of the public may like the fixed numerical value approach he says to leave it as an alternative.
4. Would like to see simulations that incorporate switching between low and high B_{MSY} values (low and high productivity regimes) and having different control rules for increasing vs decreasing B_{MSY}.
5. There was a suggestion that we could have a steeper slope at beta in the control rule instead of simply going to zero.
6. Need to add in variability in current biomass in the simulations. West coast stock assessments did not do this and it may have made a difference in the decline of stocks there.

A question was asked about how biomass estimates and reference point estimates would be determined to be reliable. For groundfish it is written in the FMP that the SSC is the ultimate decision making on that. We could do the same for crab.

A comment was made that MSST may not be appropriate for crab stocks due to high variability in recruitment.

The SSC commented that the spring CPT meeting was a good idea.

The following are the SSC's comments on the Tier System as extracted from the NPFMC's Minutes of the June 2004 SSC meeting:

> Jack Turnock (NMFS) gave a presentation on progress by a NMFS-ADF&G working group toward development of revised overfishing definitions for BS/AI crab. Gary Painter (Bering Sea Fisheries Research Foundation) provided public testimony.
>
> Principal topics discussed at the CPT meeting included implications of the data quality act on the Crab Plan Team, survey catchability studies for snow crab, industry-funded augmentation to the NMFS annual trawl survey, updates on crab rationalization, and a report on overfishing working group progress. The CPT seeks guidance from the Council as to whether the CPT should continue their spring meeting in the future in addition to their usual fall meeting. CPT members felt that the spring meeting was a useful venue to discuss important crab issues, because there is often insufficient time to do so at their fall meeting that tends to focus on stock assessments and fishery management. The SSC continues to support the CPT meeting in spring, as long as there are sufficient issues to justify this meeting.
>
> Original consideration of crab overfishing definitions occurred in April and June 1998. The SSC had several concerns about the overfishing definitions at that time. First, numerical values were used, instead of frame working a general procedure. Second, there was not always more conservatism with less information. Third, there were differences between definitions between the groundfish and the crab FMPs that did not seem to be necessary. Because the CPT was planning to review the crab definitions every five years, the SSC accepted the proposed definitions.
>
> At the February 2004 Council meeting, the SSC heard a report on the progress of the NMFS-ADF&G working group. At that time, the SSC requested that the working group focus on a careful evaluation of crab overfishing definitions, including a more formalized procedure for setting overfishing levels, such as the tier system used for groundfish. At the present meeting, an outline of such a tier system for crab was presented. The plan for further analysis, including simulation modeling, appears reasonable to the SSC and resolves many of the issues raised in 1998.
>
> The SSC offers the following comments to the Crab Working Group:
>
> - o Under tier 2, the scalar F_{Target}/F_{PMSY} is used to buffer the difference between ABC and OFL. The SSC was confused by the use of the proxy F_{PMSY} when an estimate of this value F_{MSY} is available. Part of the SSCs concern may be semantic. Perhaps it would be better to define the scalar in terms of a limit reference point (F_{Lim}), as in the National Standard Guidelines, and then to assign F_{PMSY} as the available reference point for F_{Lim}.

- Consider whether there is evidence for density dependence in biological parameters, such as growth and maturity. If so, consider including these in the analysis.

- The SSC supports the three alternatives presented (status quo, numerical values for overfishing definitions fixed in the FMP, and overfishing definitions frame worked in the FMP). These alternatives will foster an analysis of the timing and review process for stock assessment relative to overfishing on an annual basis. The SSC notes that the timing of decision-making and the overall process differ between crab and groundfish, so that there may be reasons for having fixed numerical values instead of a framework in the crab FMP.

- One weakness of constant harvest control rules for rapidly fluctuating stocks is that they may not efficiently adapt to changing conditions. The SSC would like to see an evaluation of a harvest control rule that recognizes fluctuations between different periods of productivity and the possibility of implementing a switching rule between overfishing reference points. This evaluation could consider the prospects of both higher reference points during periods of greater productivity, as well as the need to constrain harvest to avoid potential stock depletion during the next phase of low productivity.

- The working group should explicitly consider whether parameter β, the biomass below which fishing is curtailed, is also defined to be the MSST. If it is also the MSST, then the National Standard Guidelines require that a rebuilding plan be established within one year. However, a crab stock could be classified as overfished and in need of rebuilding one year, but be totally rebuilt one or two years later, independent of any management measures. This volatility in crab populations could thus create a chaotic management environment requiring continual attention to revising rebuilding plans. The SSC has learned that MSST may be of lesser importance in new National Standard Guidelines, so defining an explicit MSST may not be necessary.

- The SSC recognizes a pressing time frame for completion of this overfishing analysis, and encourages the working group to work efficiently and to provide routine updates on progress to the CPT and SSC.

VII. **Depensation in the Stock-Recruitment Relationship:**

Describing the relationship between parent stock size and subsequent recruitment to the population is a fundamental underpinning of population dynamic modeling, the definition of biological reference points, and the design of effective harvest strategies. A notable feature of the customary analytical stock-recruitment relationship, whether it be of the depensatory Ricker, or the non-depensatory Beverton-Holt form, is the expectation of increased production rate (i.e., recruits per spawner) at very low levels of spawning stock biomass (ssb) compared to that at moderate or high levels of ssb. This is expressed in the slope of the stock-recruitment curve at the origin [i.e., as ssb tends toward zero], which characterizes the resiliency of the stock to decreased abundance, whether due to fishing mortality, natural or environmental causes.

The expectation of increased productivity as the stock declines toward the origin is a highly *risk prone* assumption to the management of a stock as it results in higher target or threshold exploitation rates, and lower stock biomass thresholds than the alternatives - i.e, a shallow steepness, or depensation at low parent stock size. Indeed, the steepness parameter of the stock-recruitment relationship is critical in the design of any fisheries management system in which S-R modeling is used to set threshold rates. Ideally, the value of this parameter would be guided by empirical data. If such data are unavailable, the value of the steepness parameter should be explicitly *risk averse* as emphasized by the precautionary principle concept discussed in the NSG1.

The Majid crab stocks subject to this management plan may fall to levels of stock density where mating success is effected by the difficulty of finding mates for many obvious reasons. The reproductive dynamics and strategies of these crab species contrast the majority of Bering Sea fish stocks, for example, which undergo spawning migrations from great distances and employ broadcasting of eggs and sperm for fertilization. Crab stocks in the Gulf of Alaska declined to low levels from which they have not recovered even after more than two and one-half decades under the most extreme conservation measures. This fact contravenes the expectation of an increased production rate at low spawning stock abundance. Alternatively, if the spawner-recruit curve has a shape where expected recruits are below the replacement line at low spawning biomass levels, then the stock may have difficulty rebuilding from low levels of ssb. Such a structural derivative to the customary form of the stock-recruitment relationship is concordant with observations of the failure of GOA stocks of *C. bairdi* and *P. camtschaticus* to rebuild despite fishery closures for significant portions of the species' life span and, similarly, with Bering Sea *C. bairdi*. These stocks have demonstrated conspicuously low resiliency, and no empirical evidence exists to support compensatory responses of the stock at low spawning stock biomass as represented by a steep, or even a moderately steep slope of the S-R curve at the origin. The implication is that these stocks reach some critical biomass threshold below which recruitment generation is insufficient for stock rebuilding, or perhaps stock replacement.

Figure 1 shows a comparison of the shape of a standard Beverton-Holt spawner recruit curve with and without depensation at low spawning stock biomass. The curve with depensation falls below the replacement line at about 25% of virgin biomass (B_0) in this example. Recruits are generally less than the standard curve below about 40% of B_0. Such a % B_0 may be illustrative in prescribing the value β which represents the critical biomass threshold below which there's a low probability of stock rebuilding or stock maintenance. The β value would suggest a threshold level for management to guard against occurring. The level of depensation for crab stocks would have to be determined by examination of con-generic stocks that have collapsed and failed to rebuild after significant time periods under no fishery exploitation, or of other crustacean stocks that express similar life-history traits and reproductive strategies. With depensation, a higher level of spawning biomass would need to be maintained to prevent collapse of the stock to levels where expected recruitment may be below the replacement line.

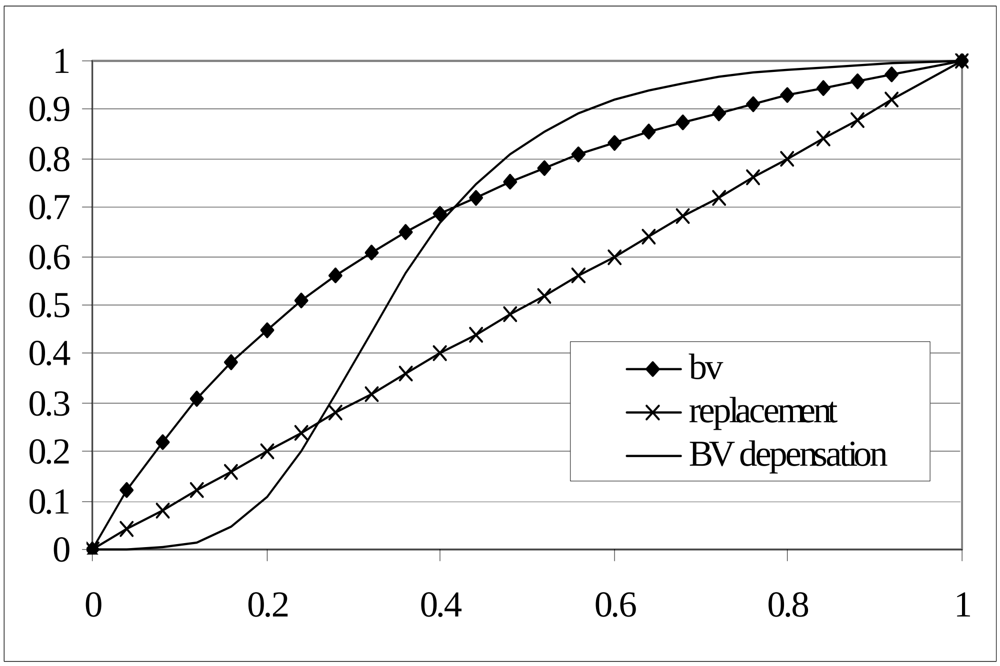


Figure 1. Example of a Beverton and Holt spawner recruit curve with and without depensation. R_0 and B_0 are 1.0 for both curves.

North Pacific Fisheries Management Council
Bering Sea / Aleutian Islands Crab Working Group Meeting
4-6 November 2003, Anchorage, AK

Meeting Agenda

Tuesday, 4 November ‘03; [1000-1700 hr]

1. Elect Working Group Chair
2. Discuss Working Group membership
3. Review / Amend Draft Agenda
4. Discuss CPT guidance to Working Group on amending the Plan
5. Discuss guidance from NPFMC, SSC or Council staff on amending Plan
6. *Lunch*
7. Distribute Lou’s 10.4.03 Addendum to CPT 22-24 Meeting Minutes
8. Review Draft Statement of Work for Working Group [Rugolo]
9. Other Issues

Wednesday, 5 November ‘03; [0800-1700 hr]

1. Finalize Statement of Work for Working Group [WG]
2. *Lunch*
3. Discuss modeling approaches to meet Action Items
4. Other Issues

Thursday, 6 November ‘03; [0800-1100 hr]

1. Develop Draft Work Plan:
    a. Work Assignments
    b. Work Time Line
2. Meeting Schedule
3. Other Issues
4. Adjourn

North Pacific Fisheries Management Council
Bering Sea / Aleutian Islands Crab Working Group Meeting
25-26 March 2004, Seattle, WA

Meeting Agenda

Thursday, 25 March 2004: [0900-1700 hr]

1. Tier System:
    a. Organizational Structure
    b. Basis of Different Tiers
    c. Proxies for B_{MSY} and MSY
    d. α, β, γ Parameters
    e. Stock-Recruitment Depensation
2. *Lunch*
3. Life-History Parameters as Inputs
    a. Empirical vs Model-Based Estimates
    b. Theoretical Considerations
4. Projection Modeling:
    a. Recruitment Generation
    b. Scenarios:
        i. Fishing Mortality Rate [F]
        ii. Projection Time Period
        iii. Rebuilding Trajectories in Biomass
        iv. Rebuilding Monitoring / Assessment

Friday, 26 March 2004: [0830-1700 hr]

1. Tier System Background / Writeup
2. Presentations:
    a. Review Conceptual / Computational Framework of Life-Table Modeling
    b. M Estimation: Practical Application of Longevity Theory
3. *Lunch*
4. Council Meeting Schedule
    a. SSC Presentation
5. Items Not Covered
    a. Life-History Table
    b. Terminal Molt in *Chionoecetes*
    c. Review Process
    d. Next Meeting

North Pacific Fisheries Management Council
Bering Sea / Aleutian Islands Crab Working Group Meeting
2-4 June 2004, Seattle, WA

Meeting Agenda

KEY: Normal Text = covered; *Italic Text* = partially covered; **Bold Text** = not covered

Wednesday, 2 June 2004: [0900-1700 hr]

1. Review / Amend Draft Agenda
2. Meeting Minutes
    a. Administrative Record
    b. Summary Overview vs Complete
3. Tier System:
    a. Goal
    b. MSY Control Rule vs Harvest Control Rule
    c. Conceptual Framework
        i. Organizational Structure
        ii. Basis of Different Tiers
        iii. α, β Parameters
    d. Stock-Recruitment Depensation
    e. Proxy B_{MSY} and MSY Values
        i. Life-History Strategies / Recruitment Dynamics
    f. Shape of MSY Control Rule
        i. Buffer Zone: F_{OFL} vs F_{TARGET}
        ii. Precautionary Principle re: Overfishing & Rebuilding
    g. Tier Assignment of Stocks
        i. Information Reliability
        ii. Static [Fixed in FMP] vs Dynamic [Defined in SAFE]
    h. Revised NSG1 re: MSST Definition

Thursday, 3 June 2004: [0900-1700 hr]

1. Terminal Molt in *Chionoecetes* sp.
    a. *opilio* [Rugolo et al., Tamone, ...]
    b. *bairdi* [Donaldson, Paul, Munk, ...]
2. Modeling Activities of Working Group
    a. Authorship vs Stewardship
    b. Documentation & Code
    c. Information Requests / Configurations

3. Life-History Parameters as Inputs
    a. Empirical vs Model-Based Estimates
    b. Theoretical Considerations
    c. M Estimation: Practical Application of Longevity Theory
4. Life-History Table
    a. Selection of Parameter Sets
    b. Time Periods to Select for Tier 6 Stocks
5. RACE Discussion with Conan
6. Mating Ratio
7. Polygyny & Polyandry
8. Effective Spawning Biomass
9. Shell Aging Errors & Uncertainties
    a. Tagging Data
    b. Effect on Precautionary Principle
10. Male Maturity and Mating Success
    a. Availability of Molting Males

Friday, 5 June 2004: [0900-1700 hr]

1. Working Group Report:
    a. Draft Outline
    b. Schedule of Work Activities
2. Modeling Aspects
    a. How to Define Proxy Values
    b. How to Define Effective Spawning Biomass
3. Recruitment Scenarios to Consider in Simulations
    a. Constant vs Periodic
    b. Autocorrelated
    c. Proxies for Recruitment Scenarios
4. Stock Recruitment Modeling
    a. Model Form [Ricker vs Beverton-Holt]
    b. Range of Models to Consider
    c. Steepness Parameter
    d. Depensation
    e. Quantifiy β Parameters

5. MSY Contol Rule

   a. Slope of Line [α Parameter]

   b. Defintion of Buffer Zone

      i. Ratio of F_{TARGET} / F_{MSY}

   c. Definition of Effective Spawning Biomass

      i. Annual vs Biennial Reproductive Cycles

      ii. Definition of Proxy Values

6. Next Meeting

North Pacific Fisheries Management Council
Bering Sea / Aleutian Islands Crab Working Group Meeting
1-3 September 2004, Anchorage, AK

Meeting Agenda

Wednesday, 1 September 2004: [1000-1800 hr]

1. Discuss Draft Agenda
2. Report on June '04 SSC Meeting Minutes:
   Working Group Presentation on Draft Tier System and Overfishing Definitions
   a. Amendment Alternatives for Environmental Assessment
   b. Definition in FMP on How Overfishing is to be Determined
   c. Current Proxy Values for B_{MSY}
      i. Definition of New Proxy Values
   d. Consideration of Variability in Biomass for Stock Simulations + Projections
   e. Size of Buffer Zone: F_{OFL} vs F_{TARGET}
   f. Consideration of Serial and Random Variation in Recruitment on Definitions
   g. High vs Low Productivity Periods and Effect on MSY Control Rule
   h. Specification of F_{LIMIT} as Proxy for F_{MSY}
   i. MSST as Threshold Given High Natural Recruitment Variability
3. Depensatory Stock-Recruitment:
   a. Model Form [Ricker vs Beverton-Holt]
   b. Ranges of Models to Consider
   c. Steepness Parameter
   d. Quantifying Tier System β Parameter
   e. Scaling Depensation to Critical Biomass Threshold

Thursday, 2 September 2004: [0830-1930 hr]

1. Specification Contents Draft Progress Report to CPT
   a. Work Plan Overview
      i. Listing / Description of Action Items
   b. Revised Tier System
      i. Turnock's Report - Extract / Insert
      ii. Graphs of MSY Control Rules
   c. NPFMC SSC Presentations:
      i. Summary Pertinent Comments Feb., '04 Meeting: on Work Plan
      ii. Summary Pertinent Comments Jun., '04 Meeting: on Tier System
   d. Critical Biomass [β] Parameter
      i. Overview of Concept:

        ii. Examination Historical Data for Insight re: Level @ Cascade Failure
        iii. Likelihood of Theoretical Value as Fixed Percentage of B_o
    e. Analytical Progress
        i. Theoretical Analytical Framework Underlying BRP Approach: Produced for All 22 BS Crab Stocks
        ii. Description of Full Set Reference Point Output
        iii. Proxy Reference Points for Data Poor Stocks
        iv. Turnock's Approach for Opilio as Redundancy
        v. Preliminary Results
    f. Remaining Work Tasks:
        i. Specification of Method to Reach Status Determination Criteria of Overfishing and Overfished
        ii. Limit Reference Point System:
            o Status of Stocks Determination
            o γ Scaler to MSY Control Rule
            o Quinn's High/Low Productivity Periods
            o Conservation Equivalency
    g. Schedule of Future Activities
2. Peer Review of Draft Report: CIE vs Co-Opted Experts
    a. Regional Experts
    b. Timing wrt CPT and Council Submissions
3. Opilio Spatial Distribution and Reproductive Dynamics wrt Biological Reference Points and Quota Setting
4. Review Draft Working Group Report

<u>Friday, 3 September 2004: [0830-1500 hr]</u>

1. Continued Analytical Work / Model Development for Estimation of BRPs
    a. Deterministic Model Structure
    b. Stochastic Approach with Recruitment Variability
    c. Stochastic Approach with Random Recruitment
2. Evolution of Draft Tier System